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By: Judith Muzyk Date: December 1, 2003
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Docket No.: 448/9-1850

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

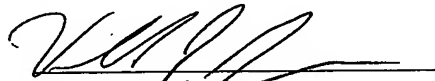
Applicant: Simon KELLY, et al Conf. No. 1665
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For: VIDEO COMPRESSION

TRANSMITTAL LETTER

Sir:

Enclosed is the certified copy of United Kingdom Priority Document No. 0217770.7 for the above referenced application. The date of certification is August 5, 2003, and the document is submitted to perfect the applicant's claim for priority.

Respectfully submitted,


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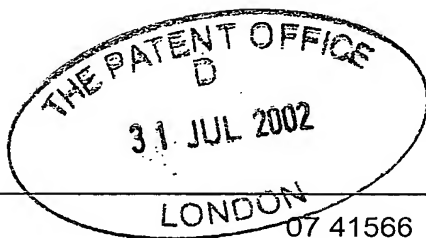
Dated 5 August 2003

Request for grant of a patent

1/77

The Patent Office

Cardiff Road
Newport
Gwent NP9 1RH



1. Your reference 07 41566

2. Patent application number
0217770.7

31 JUL 2002

3. Full name, address and post code of the or each applicant

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Patents ADP number

If the applicant is a corporate body, give the country/state of its incorporation

UK

7844 673001

4. Title of the invention VIDEO COMPRESSION

5. Name of your agent VENNER, SHIPLEY & CO

"Address for service" in the United Kingdom to which all correspondence should be sent

20 LITTLE BRITAIN
LONDON
EC1A 7DH

Patents ADP

1669004

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or each of these earlier applications and the or each application number	Country	Priority application number	Date of filing

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11. I/We request the grant of a patent on the basis of this application.

Signature

Stuart Geary

Date

31 July 2002

12. Name and daytime telephone number of person to contact in the United Kingdom

STUART GEARY
020 7600 4212

Video Compression

Description

The present invention relates to video compression.

5

WO01/65858 discloses a method of compressing video signals in which complementary sets of pixels are removed from the odd-numbered and even-numbered frames of a video signal. A removed pixel is reconstructed using the values for that pixel in the preceding and succeeding frames and the neighbouring pixels above and below in the same frame.

10

Although WO01/65858 discloses using different regeneration techniques for "moving" and "static" pixels, the method disclosed can produce unwanted artefacts in the restored video under certain circumstances.

15

It is an aim of the present invention to provide an improved video compression and decompression systems with improved identification of static pixels.

20

According to the present invention there is provided a method of transmitting a video signal, the method comprising:

removing complementary sets of pixels from alternate frames of a video signal to produce a compressed video signal;

transmitting said compressed video signal;

receiving the transmitted compressed video signal; and

25

regenerating said removed pixels, by processes selected in dependence on whether a pixel to be regenerated is determined to be static or moving, to decompress said compressed video signal,

30

wherein the determination of a pixel being static comprises determining whether its change with time meets a predetermined threshold criterion or, if said criterion is not met, whether the pixels neighbouring said pixel are more similar to each other than to a temporally interpolated value for said pixel.

Preferably, said determinations of pixels being static is performed after said reception of the compressed video.

5 A method of decompressing a video signal, which has been compressed by the removal of complementary sets pixels from alternate frames, the method comprising regenerating removed pixels, missing from the signal to be decompressed, by processes selected in dependence on whether a pixel to be regenerated is determined to be static or moving, to decompress said compressed video signal, wherein the determination of a pixel being static comprises determining whether its
10 change with time meets a predetermined threshold criterion or, if said criterion is not met, whether the pixels neighbouring said pixel are more similar to each other than to a temporally interpolated value for said pixel.

15 Preferably, said determination of whether the change of a pixel with time meets a predetermined threshold criterion comprises calculating the difference between the corresponding pixels of the preceding and succeeding frames and comparing this difference with a threshold criterion. More preferably, said determination of whether the pixels neighbouring said pixel are more similar to each other than to a temporally interpolated value for said pixel comprises comparing, on the one hand,
20 the difference between a interpolation between said corresponding pixels and the difference between said corresponding pixels and, on the other hand, a spatial interpolation between neighbouring pixels in the current frame. One or both of said interpolations may be means.

25 Preferably, said neighbouring pixels are the pixels adjacent to the pixel to be regenerated which have not themselves required regeneration.

The process selected for static pixels may comprise selecting the corresponding pixel of the preceding or succeeding frame. Preferably, however, the process
30 selected for static pixels comprises interpolating between the corresponding pixels of the preceding and succeeding frames.

Preferably, the process selected for moving pixels comprises interpolating spatially between neighbouring pixel which did not require regeneration. More preferably, the process selected for moving pixels comprises interpolating spatially between neighbouring pixel which did not require regeneration and temporally between
5 corresponding pixels in preceding and succeeding frames.

The detection of static/moving pixels from the compressed signal can be replaced by analysing the uncompressed signal and encoding into the compressed signal information for indicating selection of the optimal regeneration process.

10

According to the present invention, there is provided another method of transmitting a video signal, the method comprising:

removing complementary sets of pixels from alternate frames of a video signal to produce a compressed video signal;

15 transmitting said compressed video signal;

receiving the transmitted compressed video signal; and

regenerating said removed pixels to decompress said compressed video signal,

wherein data representing retained pixels is modified to indicate a
20 regeneration process for respective removed pixels and regeneration of removed pixels is performed using a process selected in dependence on the state of the data representing the associated retained pixel.

According to the present invention, there is provided a method of compressing a
25 video signal, the method comprising removing complementary sets of pixels from alternate frames of a video signal to produce a compressed video signal, wherein data representing retained pixels is modified to indicate a regeneration process for respective removed pixels and regeneration of removed pixels is performed using a process selected in dependence on the state of the data representing the associated
30 retained pixel.

According to the present invention, there is provided a method of decompressing a video signal, which has been compressed by the removal of complementary sets

pixels from alternate frames and the modification of digital codes for remaining pixels to indicate whether removed pixels are static or moving, the method comprising regenerating removed pixels, missing from a video signal to be decompressed, to decompress said compressed video signal, wherein data
5 representing retained pixels is modified to indicate a regeneration process for respective removed pixels and regeneration of removed pixels is performed using a process selected in dependence on the state of the data representing the associated retained pixel.

10 The data representing retained pixels may be modified to indicate whether removed pixels are static or moving. A bit of said data may be set in dependence on whether the associated removed pixel is static or moving, in which case the process selected for static pixels may comprise selecting the corresponding pixel of the preceding or succeeding frame or interpolating between the corresponding pixels of the
15 preceding and succeeding frames. More preferably, however, the process selected for moving pixels comprises interpolating spatially between neighbouring pixel which did not require regeneration, in which case the process selected for moving pixels preferably comprises interpolating spatially between neighbouring pixel which did not require regeneration and temporally between corresponding pixels in
20 preceding and succeeding frames.

Preferably, the data representing retained pixels is modified to indicate which of a plurality of processes is to be used for regenerating the associated removed pixels. More preferably, said data is modified in dependence on which of a plurality of
25 pixels and/or temporal and/or spatial averages of pixels best matches the associated removed pixels. Still more preferably, the removed pixels are regenerated using the values from the pixels and/or averages indicated by the modification to said data. Conveniently, the least significant bits of each component (e.g. RGB or YUV) of the data representing a retained pixel form a code indicating said best match.

30 The compression methods of the present invention may be supplemented by subsequent further compression, for example wavelet or MPEG compression.

The present invention also provided apparatus, such as computers, configured for performing methods according to the present invention and to signals, and recordings thereof, representing codes for controlling a computer to perform a method according to the present invention.

5

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a block diagram of a computer configured for performing a first compression method according to the present invention;

10 Figure 2 illustrates a first compression method according to the present invention;

Figure 3 is a block diagram of a computer configured for performing a first decompression method according to the present invention;

Figure 4 is a flowchart of a first thread of a decompression program according to the present invention;

15 Figure 5 is a flowchart of a second thread of a decompression program according to the present invention;

Figure 6 illustrates a second compression method according to the present invention;

Figure 7 is a flowchart illustrating part of the method of Figure 6 in more detail;

20 Figure 8 is a flowchart of a second thread of another decompression program according to the present invention;

Figure 9 is a flowchart illustrating part of a compression method in detail;

Figure 10 is a flowchart of a second thread of yet another decompression program according to the present invention;

25 Figure 11 is a block diagram of a hybrid compression system according to the present invention; and

Figure 12 is a block diagram of a hybrid decompression system according to the present invention.

30 In the following description, 10 by 10 pixel frames will be used to illustrate the present invention. This is purely for the purpose of making the present invention more readily comprehensible and the 10 by 10 pixel frames are to be understood to represent frames having more conventional and much large numbers of pixels.

A first embodiment of the compression aspect of the present invention will now be described.

5 Referring to Figure 1, a computer comprises a CPU (central processing unit) 1, a level 2 cache connected to the CPU 1 by a backside bus 3, a bridge 4 interfacing a system bus 5 and a PCI bus 6 and a memory controller 7 connected to the bridge 4 and the cache 2 and to a plurality of RAM modules 8. A graphics controller 9, a video capture card 10 and a hard disk 11 are connected to the PCI bus 6. The hard
10 disk 11 stores programs for controlling the computer, including a video compression program, which is loaded into RAM for execution. The hard disk 11 is also used to store compressed video.

Referring to Figure 2, during video compression, video frames 14 are captured by
15 the video capture card 10 (step s1). When a frame 14 has been captured, it is determined whether it is odd, i.e. first, third, fifth, ..., or even, i.e. second, fourth, sixth, ..., (step s2). If the frame 14 is odd, a first set of pixels is removed (step s3). However, if the frame 14 is even, a second set of pixels is removed (step s4). The first and second sets of pixels are the same size and complementary. That is, the
20 second set comprises the pixels that are not in the first set. In the present example, the removed pixels are arranged in complementary checkerboard patterns.

When the appropriate pixel set has been removed, the remaining pixels are written to a file on the hard disk 11 (step s5).

25 The file of compressed video on the hard drive 11 can be transmitted across a computer network or used to modulate a carrier wave for transmission. Alternatively, the output of the compression process could be transmitted immediately across a network or on a carrier wave, rather than being stored on the
30 hard disk 11.

A first embodiment of the decompression aspect of the present invention, which can decompress video signals produced by the first embodiment of the compression aspect, will now be described.

5 Referring to Figure 3, a computer comprises a CPU (central processing unit) 101, a level 102 cache connected to the CPU 101 by a backside bus 103, a bridge 104 interfacing a system bus 105 and a PCI bus 106 and a memory controller 107 connected to the bridge 104 and the cache 102 and to a plurality of RAM modules 108. A graphics controller 109, a network interface card 110 and a hard disk 111
10 are connected to the PCI bus 106. The hard disk 111 stores programs for controlling the computer, including a video decompression program, which is loaded into RAM for execution.

Decompression involves two processes, handled by separate threads. The first
15 thread (Figure 4) deals with the reception of compressed video data and the second thread (Figure 5) deals with the regeneration of missing data.

Referring to the Figure 4, the first thread comprises a loop which reads data from the network interface card 110 and stores it in the RAM 108. More particularly, the
20 first thread initially determines whether it should terminate, e.g. due to the end of the video data stream, an exception or a user instruction, (step s11). If the thread is not to terminate, it reads the next packet of video data from the network interface card 110 and writes it to a buffer in the RAM 108 (step s12). There are four buffers, numbered 0, 1, 2 and 3, each of which can hold one compressed video
25 frame.

When the data has been written to the RAM 108, it is determined whether the buffering of a frame has been completed thereby (step s13). If the buffering of a frame has not been completed, the thread returns to step s11. However, if the
30 buffering of a frame has been completed, the buffer index is incremented (step s14). Thus, if the current buffer is 0, the new buffer is 1 and, if the current buffer is 3, the new buffer is 0.

If the frame count is greater than three, i.e. at least three complete frames have been received (step s15), the data regeneration thread is triggered (step s16). If the three complete frames have not been received at step s15 and following step s16, the thread returns to step s11.

5

Referring to Figure 5, the first step (step s21) of the regeneration thread determines whether the thread should terminate, e.g. in response to a user input. If the thread is not to terminate, it is determined whether the next pixel is present in the current buffer (step s22) on the basis of the current frame being odd or even. If the pixel is present, it is stored in an output buffer (step s26). However, if the pixel is not present, it needs to be regenerated.

10

In order to regenerate a pixel, it is first determined whether that pixel is static, i.e. in an area of the image that remains unchanged over three frames, or, conversely, moving (step s23).

15

Each pixel is represented by three bytes with the red, green and blue components being represented by respective bytes. For each colour, the difference between the corresponding pixel in the preceding and succeeding frames is calculated and compared with a threshold Δ_T

20

$$\begin{cases} \Delta_R = |p_{R(t-1)}(x, y) - p_{R(t+1)}(x, y)| \\ \Delta_G = |p_{G(t-1)}(x, y) - p_{G(t+1)}(x, y)| \\ \Delta_B = |p_{B(t-1)}(x, y) - p_{B(t+1)}(x, y)| \end{cases} \quad (1)$$

where R, G and B indicate red, green and blue respectively and x and y are the co-ordinates of the pixel to be regenerated. If any of the difference values $\Delta_R, \Delta_G, \Delta_B$ is not less than the threshold Δ_T , the pixel is determined not to be static, otherwise it is determined to be potentially static. If the current pixel is determined to be potentially static, the red, green and blue values for the current pixel ($p'_{R(t)}(x, y), p'_{G(t)}(x, y), p'_{B(t)}(x, y)$) are set respectively to the means of the red, green and blue values of the corresponding pixels of the preceding and succeeding frames.

25

Applying this algorithm alone can lead to artefacts in the displayed image due to coincidentally "static" pixels in an otherwise moving area of an image. In order to avoid such false positives, the following are calculated:

$$\begin{aligned}
 k_{Rv} &= \left| \frac{p_{R(t)}(x, y-1) + p_{R(t)}(x, y+1)}{2} - p'_{R(t)}(x, y) \right| - |p_{R(t)}(x, y-1) - p_{R(t)}(x, y+1)| \\
 k_{Gv} &= \left| \frac{p_{G(t)}(x, y-1) + p_{G(t)}(x, y+1)}{2} - p'_{G(t)}(x, y) \right| - |p_{G(t)}(x, y-1) - p_{G(t)}(x, y+1)| \\
 k_{Bv} &= \left| \frac{p_{B(t)}(x, y-1) + p_{B(t)}(x, y+1)}{2} - p'_{B(t)}(x, y) \right| - |p_{B(t)}(x, y-1) - p_{B(t)}(x, y+1)| \\
 k_{Rh} &= \left| \frac{p_{R(t)}(x, y-1) + p_{R(t)}(x, y+1)}{2} - p'_{R(t)}(x, y) \right| - |p_{R(t)}(x, y-1) - p_{R(t)}(x, y+1)| \\
 k_{Gh} &= \left| \frac{p_{G(t)}(x-1, y) + p_{G(t)}(x+1, y)}{2} - p'_{G(t)}(x, y) \right| - |p_{G(t)}(x-1, y) - p_{G(t)}(x+1, y)| \\
 k_{Bh} &= \left| \frac{p_{B(t)}(x-1, y) + p_{B(t)}(x+1, y)}{2} - p'_{B(t)}(x, y) \right| - |p_{B(t)}(x-1, y) - p_{B(t)}(x+1, y)|
 \end{aligned} \tag{2}$$

5

If any of the values k_{Rv} , k_{Gv} , k_{Bv} , k_{Rh} , k_{Gh} , k_{Bh} is greater than a threshold, the current pixel is determined not to be static after all and to be moving. Thresholds in the range 5 to 10 have been found to be usable with 24-bit colour images.

- 10 If it is finally determined that the current pixel is static, the previously calculated mean values ($p'_{R(t)}(x, y)$, $p'_{G(t)}(x, y)$, $p'_{B(t)}(x, y)$) are stored as the regenerated red, green and blue values for the current pixel (steps s24 and s26).

- 15 On the other hand, if the current pixel is determined to be moving, it is regenerated by taking the average of the surrounding four pixels in the current frame (step s25):

$$\begin{aligned}
 p'_{R(t)}(x, y) &= \frac{p_{R(t)}(x-1, y) + p_{R(t)}(x+1, y) + p_{R(t)}(x, y-1) + p_{R(t)}(x, y+1)}{4} \\
 p'_{G(t)}(x, y) &= \frac{p_{G(t)}(x-1, y) + p_{G(t)}(x+1, y) + p_{G(t)}(x, y-1) + p_{G(t)}(x, y+1)}{4} \\
 p'_{B(t)}(x, y) &= \frac{p_{B(t)}(x-1, y) + p_{B(t)}(x+1, y) + p_{B(t)}(x, y-1) + p_{B(t)}(x, y+1)}{4}
 \end{aligned} \tag{3}$$

These average values are then stored in the output buffer (step s26).

This process is repeated until the current frame has been completely regenerated, after which the regenerated frame is displayed (step s27).

5 Certain values, used in Equations (2) and (3) will not be available for pixels at the edge of a frame. To solve this, the missing pixels can be replaced with a value that is available. For instance, if there is no $p_{R(t)}(x-1, y)$ value, $p_{R(t)}(x+1, y)$ could be used instead. Alternatively, the averaging in Equations (2) and (3) could be adapted to employ only those pixel for which data exists, e.g.:

if $p_{R(t)}(x, y-1)$ does not exist,

$$10 \quad k_{Rv} = \left| \frac{p_{R(t)}(x, y-1) + p_{R(t)}(x, y+1)}{2} - p'_{R(t)}(x, y) \right| - |p_{R(t)}(x, y-1) - p_{R(t)}(x, y+1)|$$

becomes

$$k_{Rv} = |p_{R(t)}(x, y+1) - p'_{R(t)}(x, y)| - |0|$$

and

$$p'_{R(t)}(x, y) = \frac{p_{R(t)}(x-1, y) + p_{R(t)}(x+1, y) + p_{R(t)}(x, y-1) + p_{R(t)}(x, y+1)}{4}$$

15 becomes

$$p'_{R(t)}(x, y) = \frac{p_{R(t)}(x-1, y) + p_{R(t)}(x+1, y) + p_{R(t)}(x, y+1)}{3}$$

A further option is to discard the outer ring of pixels in the decompression process.

20 A second embodiment of the decompression aspect of the present invention, which can decompress video signals produced by the first embodiment of the compression aspect, will now be described.

The decompression again involves two processes, handled by separate threads. The
25 first thread is as described above with reference to (Figure 4) and deals with the reception of compressed video data. The second thread (Figure 5) deals with the regeneration of missing data.

Referring again to Figure 5, the first step (step s21) of the regeneration thread
30 determines whether the thread should terminate, e.g. in response to a user input. If

the thread is not to terminate, it is determined whether the next pixel is present in the current buffer (step s22) on the basis of the current frame being odd or even. If the pixel is present, it is stored in an output buffer (step s26). However, if the pixel is not present, it needs to be regenerated.

5

In order to regenerate a pixel, it is first determined whether that pixel is static, i.e. in an area of the image that remains unchanged over three frames (step s23).

Each pixel is represented by three bytes with the red, green and blue components being represented by respective bytes. For each colour, the difference between the corresponding pixel in the preceding and succeeding frames is calculated and

10

compared with a threshold Δ_T :

$$\begin{cases} \Delta_R = |p_{R(t-1)}(x, y) - p_{R(t+1)}(x, y)| \\ \Delta_G = |p_{G(t-1)}(x, y) - p_{G(t+1)}(x, y)| \\ \Delta_B = |p_{B(t-1)}(x, y) - p_{B(t+1)}(x, y)| \end{cases} \quad (4)$$

where R, G and B indicate red, green and blue respectively and x and y are the coordinates of the pixel to be regenerated. If any of the difference values Δ_R , Δ_G , Δ_B is not less than the threshold Δ_T , the pixel is determined not to be static, otherwise it is determined to be potentially static. If the current pixel is determined to be potentially static, the red, green and blue values for the current pixel ($p'_{R(t)}(x, y)$, $p'_{G(t)}(x, y)$, $p'_{B(t)}(x, y)$) are set respectively to those of the corresponding pixel of the preceding frame.

20

Applying this algorithm alone can lead to artefacts in the displayed image due to coincidentally "static" pixels in an otherwise moving area of an image. In order to avoid such false positives, the following are calculated:

$$\begin{cases} k_R = |p_{R(t-1)}(x, y) - p_{R(t+1)}(x, y)| - |p_{R(t)}(x, y-1) - p_{R(t)}(x, y+1)| \\ k_G = |p_{G(t-1)}(x, y) - p_{G(t+1)}(x, y)| - |p_{G(t)}(x, y-1) - p_{G(t)}(x, y+1)| \\ k_B = |p_{B(t-1)}(x, y) - p_{B(t+1)}(x, y)| - |p_{B(t)}(x, y-1) - p_{B(t)}(x, y+1)| \end{cases} \quad (5)$$

25

If any of the values k_R , k_G , k_B is greater than a threshold, the current pixel is determined not to be static after all and to be moving. Thresholds in the range 5 to 10 have been found to be usable with 24-bit colour images.

- 5 If it is finally determined that the current pixel is static, the values from the preceding frame are stored as the regenerated red, green and blue values for the current pixel (steps s24 and s26).

10 On the other hand, if the current pixel is determined to be moving, it is regenerated by taking the average of the pixels above and below in the current frame (step s25):

$$\begin{aligned} p'_{R(t)}(x, y) &= \frac{p_{R(t)}(x, y-1) + p_{R(t)}(x, y+1)}{2} \\ p'_{G(t)}(x, y) &= \frac{p_{G(t)}(x, y-1) + p_{G(t)}(x, y+1)}{2} \\ p'_{B(t)}(x, y) &= \frac{p_{B(t)}(x, y-1) + p_{B(t)}(x, y+1)}{2} \end{aligned} \quad (6)$$

These average values are then stored in the output buffer (step s26).

- 15 This process is repeated until the current frame has been completely regenerated, after which it is displayed (step s27).

Certain values, used in Equations (5) and (6) will not be available for pixels at the edge of a frame. To solve this, the missing pixels can be replaced with a value that is available. For instance, if there is no $p_{R(t)}(x-1, y)$ value, $p_{R(t)}(x+1, y)$ could be used instead. A further option is to discard the outer ring of pixels in the decompression process.

- 25 This second embodiment is simpler than the first embodiment and particularly suited to the case where alternate lines are removed in the compression process. However, it can be used with other patterns of removed pixels and it can be seen that the complexity of the decompression process can be set solely with reference to the capabilities of the decompressing apparatus. In other words, the same compressed signal can be reconstructed with different qualities by different decompression apparatuses.

A second embodiment of the compression aspect of the present invention will now be described.

5 The present embodiment uses the same hardware as the first embodiment, described with reference to Figure 1.

Referring to Figure 6, video frames 314 are captured by the video capture card 10 (step s31). When a frame 314 has been captured, it is determined whether it is odd, 10 i.e. first, third, fifth, ..., or even, i.e. second, fourth, sixth, ..., (step s32). If the frame 314 is odd, a first set of pixels is discarded (step s33) otherwise a second, complementary set of pixels is discarded (step s34). The sets of pixels comprise sets of alternate lines.

15 Referring to Figure 7, for each of the pixels to be removed, the average for each colour of the corresponding pixels in the preceding and succeeding frames is calculated (step s41) and the average for each colour of the pixels in the rows above and below (step s42) is calculated. These averages are compared with the values for the current pixel to determine the best match (step s43). If the temporal average 20 calculated at step s41 is best, the pixel is deemed to be moving and the least significant blue bit (static flag) of the pixel in the row above is set to 0 (step s44). If the temporal average is not best, the pixel is deemed to be static and the least significant blue bit (static flag) of the pixel in the row above is set to 1 (step s45). Returning to Figure 6, if the frame 314 is even, the static flags are the least 25 significant blue bits of the pixels in the same column of the following line.

When all of the static flag bits, i.e. the least significant blue bits, have been set, the remaining pixels, i.e. the odd lines of even frames and the even lines of odd frames, are written to the a file on the hard disk 11 (step s35).

30

A third embodiment of the decompression aspect of the present invention, which can decompress video signals produced by the second embodiment of the compression aspect, will now be described. The present embodiment uses the same

hardware and reception thread as the first and second embodiments, described with reference to Figures 3 and 4.

Referring to Figure 8, the first step (step s51) of the regeneration thread determines whether the thread should terminate, e.g. in response to a user input. If the thread is not to terminate, it is determined whether the next pixel is present in the current buffer (step s52) on the basis the current frame being odd or even. If the pixel is present, it is stored in an output buffer (step s56). However, if the pixel is not present, it needs to be regenerated.

10

In order to regenerate a pixel, it is first determined whether that pixel is static, i.e. in an area of the image that remains unchanged over three frames, (step s53) by checking the least significant blue bit for the pixel in the same column and preceding row for odd frames and the same column and succeeding row for even frames.

15

If the relevant static flag pixel indicates that the current pixel is static, the mean values of the red, green and blue values of the corresponding pixels in the preceding and succeeding frames are calculated and stored as the regenerated red, green and blue values for the current pixel (steps s54 and s56).

20

On the other hand, if the current pixel is determined to be moving, it is regenerated by taking the average of the pixels above and below in the current frame (step s55):

$$\begin{aligned} p'_{R(t)}(x, y) &= \frac{p_{R(t)}(x, y-1) + p_{R(t)}(x, y+1)}{2} \\ p'_{G(t)}(x, y) &= \frac{p_{G(t)}(x, y-1) + p_{G(t)}(x, y+1)}{2} \\ p'_{B(t)}(x, y) &= \frac{p_{B(t)}(x, y-1) + p_{B(t)}(x, y+1)}{2} \end{aligned} \quad (8)$$

25 These average values are then stored in the output buffer (step s56).

This process is repeated until the current frame has been completely regenerated when the regenerated frame is displayed (step s57).

As explained above, steps need to be take to deal with pixels at the edges of frames.

A third embodiment of the compression aspect of the present invention will now be described.

5

The present embodiment uses the same hardware as the first embodiment, described with reference to Figure 1.

10 Referring to Figure 2, during video compression, video frames 14 are captured by the video capture card 10 (step s1). When a frame 14 has been captured, it is determined whether it is odd, i.e. first, third, fifth, ..., or even, i.e. second, fourth, sixth, ..., (step s2). If the frame 14 is odd, a first set of pixels is removed (step s3). However, if the frame 14 is even, a second set of pixels is removed (step s4). The first and second sets of pixels are the same size and complementary. That is, the
15 second set comprises the pixels that are not in the first set. In the present example, the removed pixels are arranged in complementary checkerboard patterns.

Referring to Figure 9, for each of the pixels to be removed, the average for each colour of the corresponding pixels in the preceding and succeeding frames is
20 calculated (step s61) and the average for each colour of the pixels in the rows above and below (step s62) is calculated. The colour values for current pixel are compared with those for each of the pixel above, the pixel below, the corresponding pixel in the preceding frame, the corresponding pixel in the succeeding frame, the temporal average and the spatial average (step s63) to find the one which is closest to the
25 current pixel. The result of these comparisons is indicated using a 3-bit code comprising the least significant bit of each of the red, green and blue values of the preceding pixel for odd frames and the succeeding pixel for even frames.

If the pixel above is the best match, the code is set to 000 (step s64). If the pixel
30 below is the best match, the code is set to 001 (step s65). If the pixel to the left is the best match, the code is set to 010 (step s66). If the pixel to the right is the best match, the code is set to 011 (step s67). If the preceding corresponding pixel is the best match, the code is set to 100 (step s68). If the succeeding corresponding pixel

is the best match, the code is set to 101 (step s69). If the temporal average provides the best match, the code is set to 110 (step s70) and if the spatial average provides the best match, the code is set to 111 (step s71).

- 5 Returning to Figure 2, when all of the control bits, i.e. the least significant red, green and blue bits, have been set, the remaining pixels are written to the a file on the hard disk 11 (step s5).

- 10 A fourth embodiment of the decompression aspect of the present invention, which can decompress video signals produced by the third embodiment of the compression aspect, will now be described. The present embodiment uses the same hardware and reception thread as the first and second embodiments, described with reference to Figures 3 and 4.

- 15 Referring to Figure 10, the first step (step s81) of the regeneration thread determines whether the thread should terminate, e.g. in response to a user input. If the thread is not to terminate, it is determined whether the next pixel is present in the current buffer (step s82) on the basis the current frame being odd or even. If the pixel is present, it is stored in an output buffer (step s84). However, if the pixel
20 is not present, it needs to be regenerated.

- In order to regenerate a pixel, it is first determined how that pixel is to be regenerated by reading the code formed by the least significant red, green and blue bits of the preceding or succeeding pixel, depending on whether the current frame is
25 odd or even, and the performing the appropriate regeneration process, i.e. using the pixel above, the pixel below, the pixel to the left, the pixel to the right, the corresponding pixel in the preceding frame, the corresponding pixel in the succeeding frame, the average of the pixels above and below or the average of the corresponding pixels in the preceding and succeeding frames (step s83).

- 30 This process is repeated until the current frame has been completely regenerated (step s85), when the regenerated frame is displayed (step s86).

As explained above, steps need to be take to deal with pixels at the edges of frames.

Referring to Figure 11, a hybrid video compression system comprises a first
compression stage 201, which is any of the compressions systems described above,
5 and a second compression stage 202 comprising an MPEG coder. The first
compression stage 201 receives a video signal and compresses it by removing pixels
by the first compression method described above. The output of the first
compression stage 202 is input into the second compression stage 202 where it is
further compressed and incorporated into an MPEG-2 transport stream with an
10 accompanying audio signal.

Referring to Figure 12, a hybrid video decompression system, for decompressing
signals produced by the compression system illustrated in Figure 9, comprises a first
decompression stage 203, comprising an MPEG decoder, and a second
15 decompression stage 204, which is any decompression system as described above.
An MPEG-2 transport stream is received by the first decompression stage 203
which extracts and decodes an audio component, if any, and decodes a video
component which is output to the second decompression stage 204. The second
decompression stage 204 processes the decoded video components to regenerate
20 the missing pixels and outputs the reconstructed video signal.

Claims

1. A method of transmitting a video signal, the method comprising:
removing complementary sets of pixels from alternate frames of a video
5 signal to produce a compressed video signal;
transmitting said compressed video signal;
receiving the transmitted compressed video signal; and
regenerating said removed pixels, by processes selected in dependence on
whether a pixel to be regenerated is determined to be static or moving, to
10 decompress said compressed video signal,
wherein the determination of a pixel being static comprises determining
whether its change with time meets a predetermined threshold criterion or, if said
criterion is not met, whether the pixels neighbouring said pixel are more similar to
each other than to a temporally interpolated value for said pixel.
15
2. A method according to claim 1, wherein said determination of whether the
change of a pixel with time meets a predetermined threshold criterion comprises
calculating the difference between the corresponding pixels of the preceding and
succeeding frames and comparing this difference with a threshold criterion.
20
3. A method according to claim 2, wherein said determination of whether the
pixels neighbouring said pixel are more similar to each other than to a temporally
interpolated value for said pixel comprises comparing, on the one hand, the
difference between a interpolation between said corresponding pixels and the
25 difference between said corresponding pixels and, on the other hand, a spatial
interpolation between neighbouring pixels in the current frame.
4. A method according to claim 3, wherein one or both of said interpolations
are means.
30
5. A method according to any preceding claim, wherein said neighbouring
pixels are the pixels adjacent to the pixel to be regenerated which have not
themselves required regeneration.

6. A method according to any preceding claim, wherein the process selected for static pixels comprises selecting the corresponding pixel of the preceding or succeeding frame.

5

7. A method according to any one of claims 1 to 5, wherein the process selected for static pixels comprises interpolating between the corresponding pixels of the preceding and succeeding frames.

10 8. A method according to any preceding claim, wherein the process selected for moving pixels comprises interpolating spatially between neighbouring pixel which did not require regeneration.

9. A method according to claim 8, wherein the process selected for moving
15 pixels comprises interpolating spatially between neighbouring pixel which did not require regeneration and temporally between corresponding pixels in preceding and succeeding frames.

10. A method according to any preceding claim, wherein said determinations of
20 pixels being static is performed after said reception of the compressed video.

11. A method of transmitting a video signal, the method comprising:
removing complementary sets of pixels from alternate frames of a video
signal to produce a compressed video signal;
25 transmitting said compressed video signal;
receiving the transmitted compressed video signal; and
regenerating said removed pixels to decompress said compressed video
signal,
wherein data representing retained pixels is modified to indicate a
30 regeneration process for respective removed pixels and regeneration of removed
pixels is performed using a process selected in dependence on the state of the data
representing the associated retained pixel.

12. A method according to claim 11, wherein the data representing retained pixels is modified to indicate whether removed pixels are static or moving.

13. A method according to claim 12, wherein a bit of said data is set in
5 dependence on whether the associated removed pixel is static or moving.

14. A method according to claim 12 or 13, wherein the process selected for static pixels comprises selecting the corresponding pixel of the preceding or succeeding frame.

10

15. A method according to claim 12 or 13, wherein the process selected for static pixels comprises interpolating between the corresponding pixels of the preceding and succeeding frames.

16. A method according to any one of claims 12 to 15, wherein the process
15 selected for moving pixels comprises interpolating spatially between neighbouring pixel which did not require regeneration.

17. A method according to claim 16, wherein the process selected for moving
20 pixels comprises interpolating spatially between neighbouring pixel which did not require regeneration and temporally between corresponding pixels in preceding and succeeding frames.

18. A method according to claim 11, wherein the data representing retained
25 pixels is modified to indicate which of a plurality of processes is to be used for regenerating the associated removed pixels.

19. A method according to claim 18, wherein said data is modified in
30 dependence on which of a plurality of pixels and/or temporal and/or spatial averages of pixels best matches the associated removed pixels.

20. A method according to claim 19, wherein the removed pixels are regenerated using the values from the pixels and/or averages indicated by the modification to said data.

5 21. A method according to claim 19 or 20, wherein the least significant bits of each component of the data representing a retained pixel form a code indicating said best match.

10 22. A method of decompressing a video signal, which has been compressed by the removal of complementary sets pixels from alternate frames, the method comprising regenerating removed pixels, missing from the signal to be decompressed, by processes selected in dependence on whether a pixel to be regenerated is determined to be static or moving, to decompress said compressed video signal, wherein the determination of a pixel being static comprises
15 determining whether its change with time meets a predetermined threshold criterion or, if said criterion is not met, whether the pixels neighbouring said pixel are more similar to each other than to a temporally interpolated value for said pixel.

20 23. A method according to claim 22, wherein said determination of whether the change of a pixel with time meets a predetermined threshold criterion comprises calculating the difference between the corresponding pixels of the preceding and succeeding frames and comparing this difference with a threshold criterion.

25 24. A method according to claim 23, wherein said determination of whether the pixels neighbouring said pixel are more similar to each other than to a temporally interpolated value for said pixel comprises comparing, on the one hand, the difference between a interpolation between said corresponding pixels and the difference between said corresponding pixels and, on the other hand, a spatial interpolation between neighbouring pixels in the current frame.

30 25. A method according to claim 24, wherein one or both of said interpolations are means.

26. A method according to any one of claims 22 to 25, wherein said neighbouring pixels are the pixels adjacent to the pixel to be regenerated which have not themselves required regeneration.

5 27. A method according to any one of claims 22 to 26, wherein the process selected for static pixels comprises selecting the corresponding pixel of the preceding or succeeding frame.

28. A method according to any one of claims 22 to 26, wherein the process
10 selected for static pixels comprises interpolating between the corresponding pixels of the preceding and succeeding frames.

29. A method according to any one of claims 22 to 28, wherein the process selected for moving pixels comprises interpolating spatially between neighbouring
15 pixel which did not require regeneration.

30. A method according to claim 29, wherein the process selected for moving pixels comprises interpolating spatially between neighbouring pixel which did not require regeneration and temporally between corresponding pixels in preceding and
20 succeeding frames.

31. An apparatus configured to perform a method according to any one of claim 22 to 30.

25 32. An apparatus according to claim 31, comprising a programmed computer.

33. A signal representing program codes for controlling a computer to perform a method according to any one of claims 22 to 30.

30 34. A signal according to claim 33, comprising an electrical, optical or electromagnetic signal.

35. A data carrier carrying a recording of a signal according to claim 34.

36. A method of decompressing a video signal, which has been compressed by the removal of complementary sets pixels from alternate frames and the modification of digital codes for remaining pixels to indicate whether removed
5 pixels are static or moving, the method comprising regenerating removed pixels, missing from a video signal to be decompressed, to decompress said compressed video signal, wherein data representing retained pixels is modified to indicate a regeneration process for respective removed pixels and regeneration of removed pixels is performed using a process selected in dependence on the state of the data
10 representing the associated retained pixel.

37. A method according to claim 36, wherein the data representing retained pixels has been modified to indicate whether removed pixels are static or moving.

15 38. A method according to claim 37, wherein a bit of said data is set in dependence on whether the associated removed pixel is static or moving.

39. A method according to claim 36 or 37, wherein the process selected for static pixels comprises selecting the corresponding pixel of the preceding or
20 succeeding frame.

40. A method according to claim 36 or 37, wherein the process selected for static pixels comprises interpolating between the corresponding pixels of the preceding and succeeding frames.
25

41. A method according to any one of claims 36 to 40, wherein the process selected for moving pixels comprises interpolating spatially between neighbouring pixel which did not require regeneration.

30 42. A method according to claim 41, wherein the process selected for moving pixels comprises interpolating spatially between neighbouring pixel which did not require regeneration and temporally between corresponding pixels in preceding and succeeding frames.

43. A method according to claim 36, wherein the data representing retained pixels has been modified to indicate which of a plurality of processes is to be used for regenerating the associated removed pixels.

5

44. A method according to claim 43, wherein said data has been modified in dependence on which of a plurality of pixels and/or temporal and/or spatial averages of pixels best matches the associated removed pixels.

10 45. A method according to claim 44, wherein the removed pixels are regenerated using the values from the pixels and/or averages indicated by the modification to said data.

46. A method according to claim 44 or 45, wherein the least significant bits of
15 each component of the data representing a retained pixel form a code indicating said best match.

47. An apparatus configured to perform a method according to any one of claim 36 to 46.

20

48. An apparatus according to claim 47, comprising a programmed computer.

49. A signal representing program codes for controlling a computer to perform a method according to any one of claims 36 to 46.

25

50. A signal according to claim 49, comprising an electrical, optical or electromagnetic signal.

51. A data carrier carrying a recording of a signal according to claim 50.

30

51. A method of compressing a video signal, the method comprising removing complementary sets of pixels from alternate frames of a video signal to produce a compressed video signal, wherein data representing retained pixels is modified to

indicate a regeneration process for respective removed pixels and regeneration of removed pixels is performed using a process selected in dependence on the state of the data representing the associated retained pixel.

5 52. A method according to claim 51, wherein the data representing retained pixels is modified to indicate whether removed pixels are static or moving.

53. A method according to claim 52, wherein a bit of said data is set in dependence on whether the associated removed pixel is static or moving.

10

54. A method according to claim 51, wherein the data representing retained pixels is modified to indicate which of a plurality of processes is to be used for regenerating the associated removed pixels.

15 55. A method according to claim 54, wherein said data is modified in dependence on which of a plurality of pixels and/or temporal and/or spatial averages of pixels best matches the associated removed pixels.

20 56. A method according to claim 54 or 55, wherein the least significant bits of each component of the data representing a retained pixel form a code indicating said best match.

57. A method according to any one of claims 1 to 10, including a further compression step before transmission of the compressed video and a
25 complementary further decompression step after reception of the compressed video.

58. A method of decompressing a video signal comprising:-
performing a first decompression process on a twice compressed video
30 signal to produce a once compressed video signal; and
performing a method according to any one of claims 22 to 30 to produce an uncompressed video signal.

Abstract

Video Compression

Video signals are compressed by removing complementary sets of pixels from
5 alternate frames. In one embodiment, the removed pixels are determined to be
static or moving, from an analysis of the temporally and spatially neighbouring
remaining pixels and reconstructed by processes selected in dependence on whether
they are static or moving. In another embodiment, the selection or combination of
temporally and/or spatially neighbouring pixels required to reconstruct removed
10 pixels is embedded in the data code of remaining pixels.

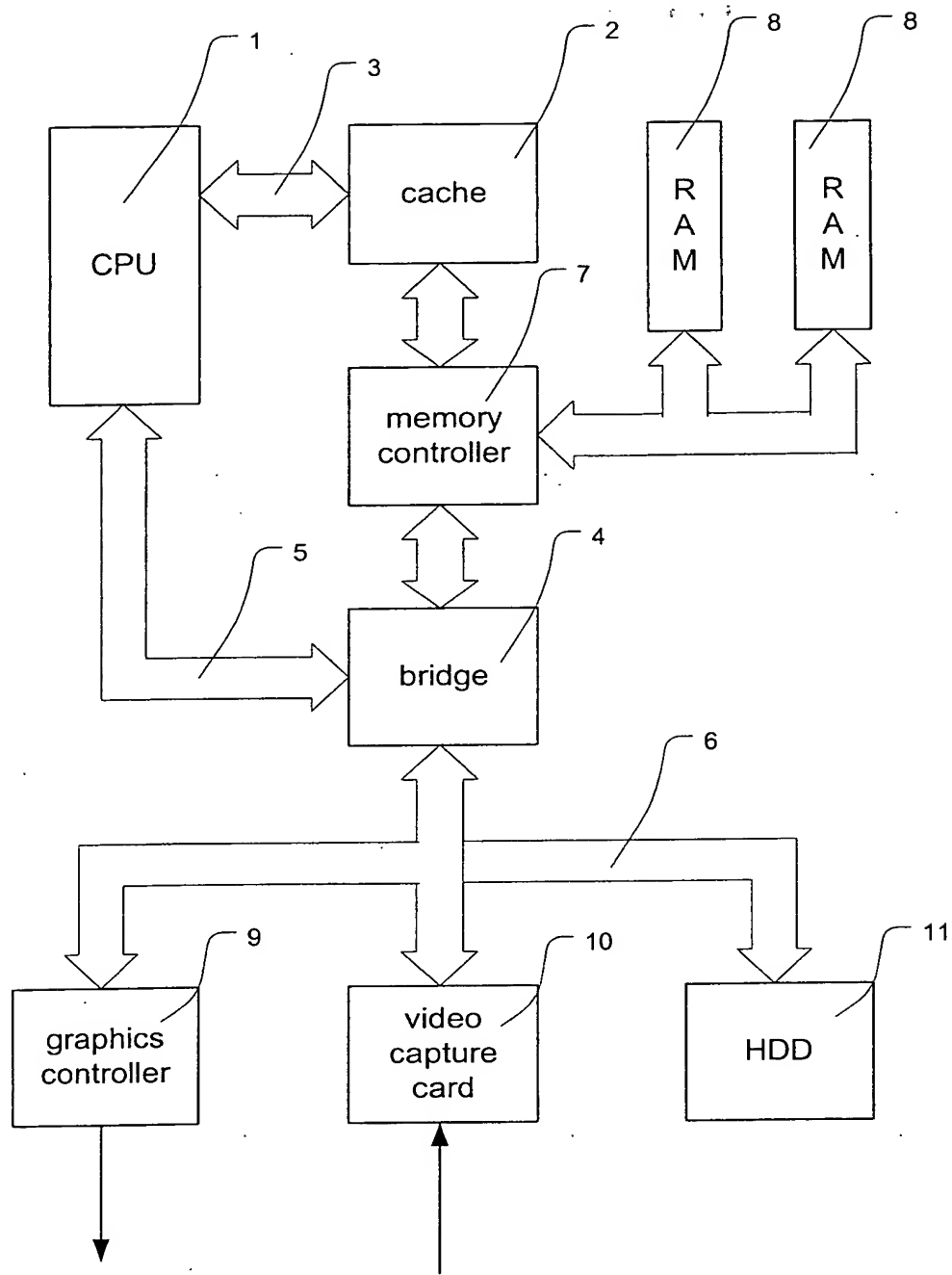
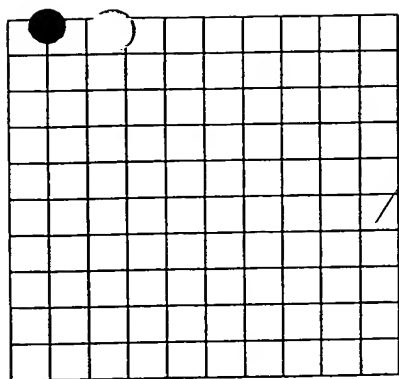


Figure 1



14

s1 - capture
video frame

s2 - odd?

Yes

No

s3 - discard
first pixel set

s4 - discard
second pixel set

s5 - store
video frame

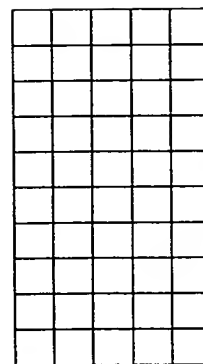
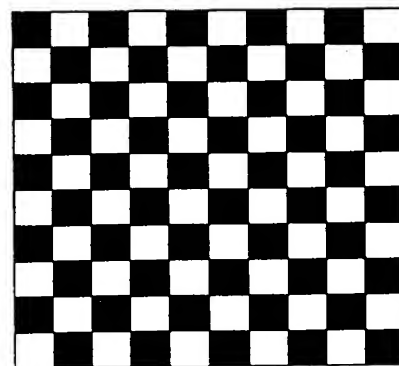
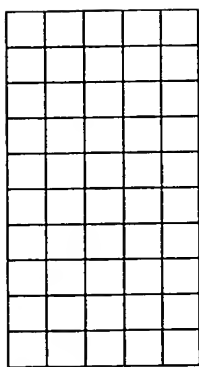
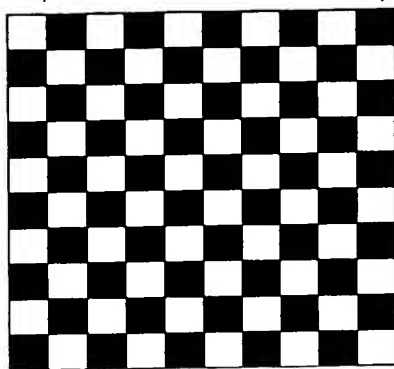


Figure 2

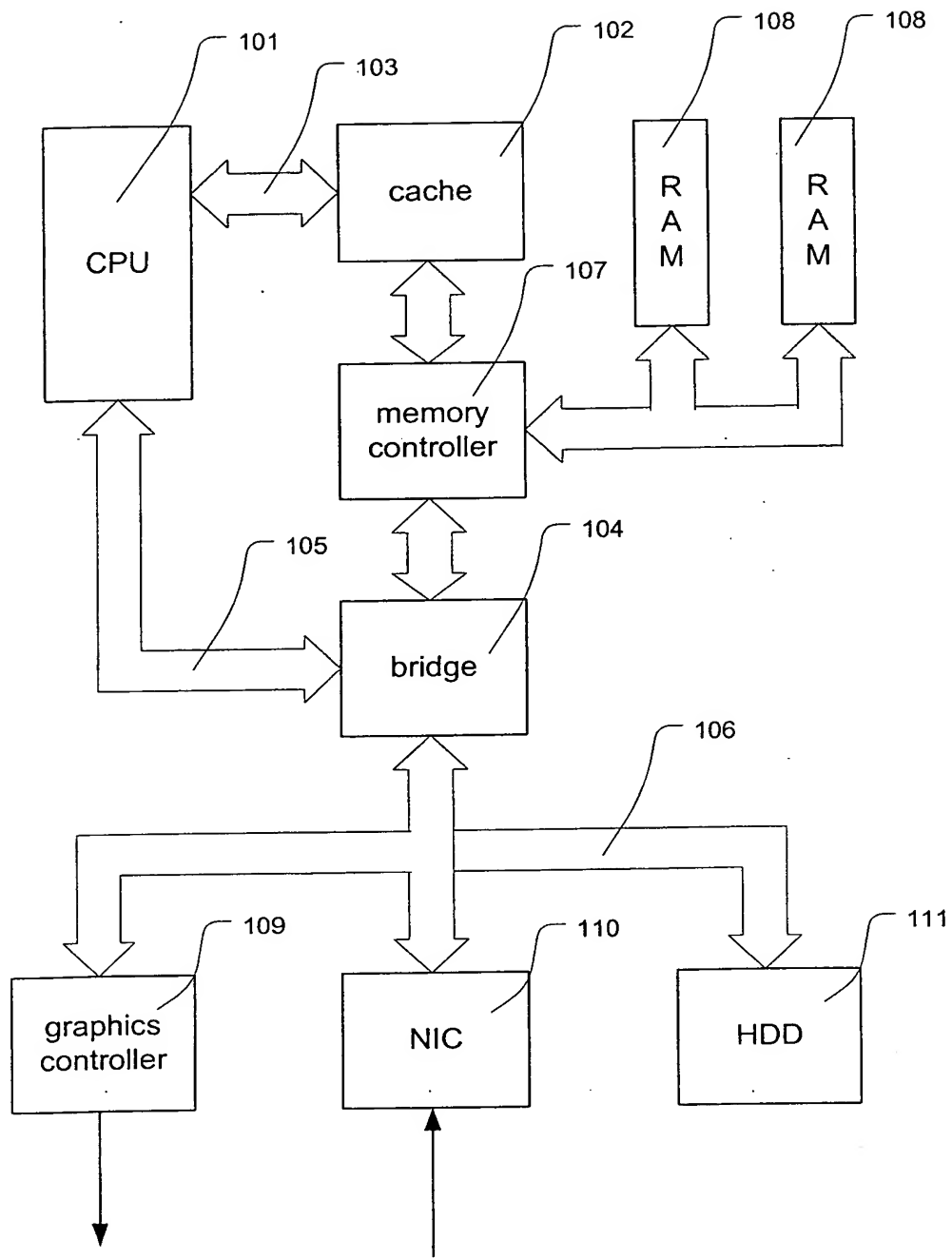


Figure 3

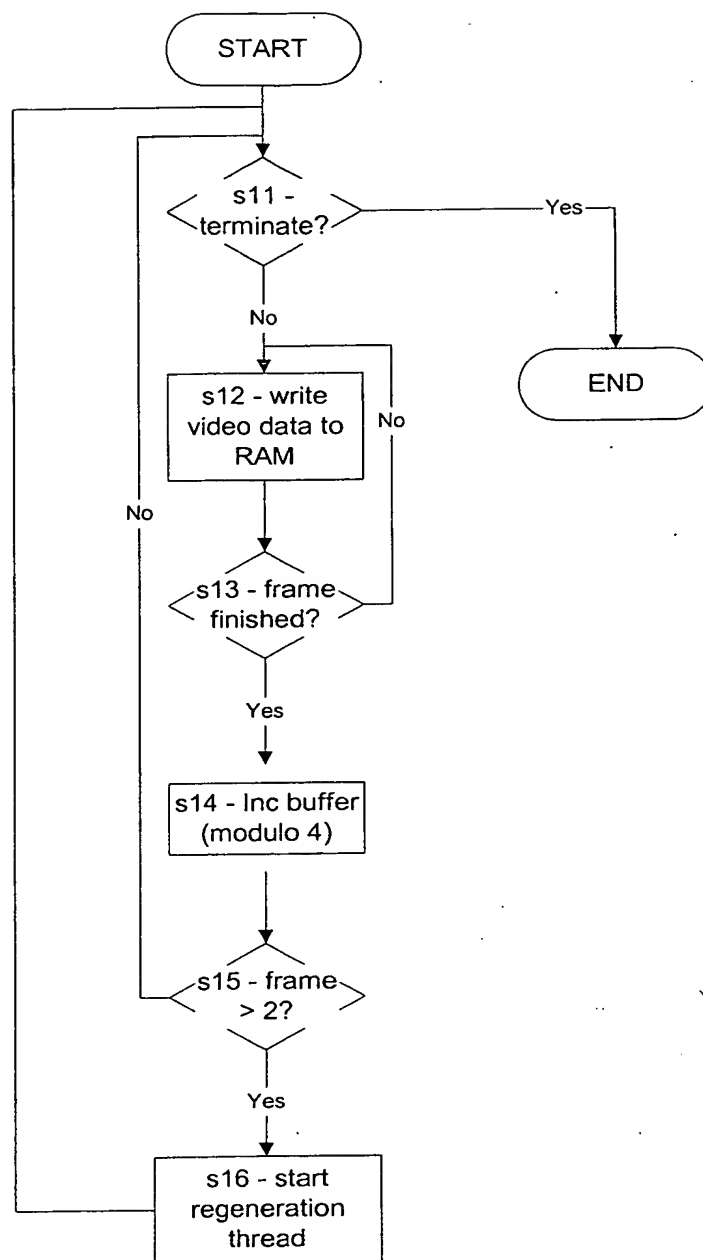


Figure 4

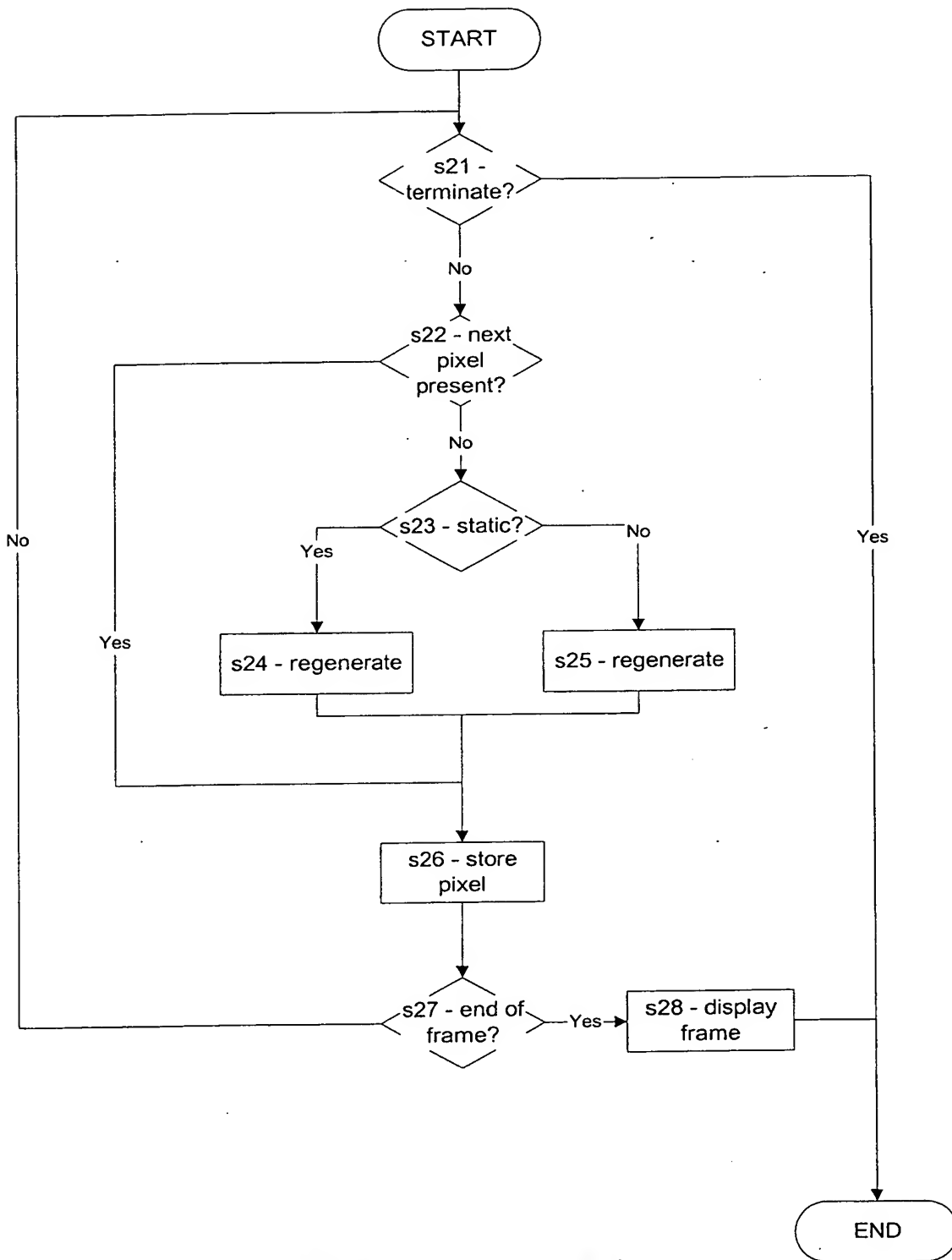


Figure 5

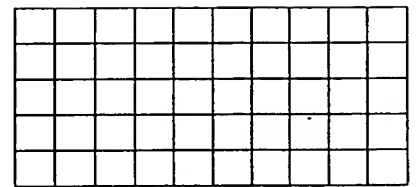
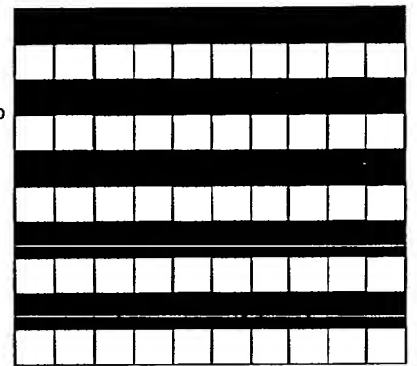
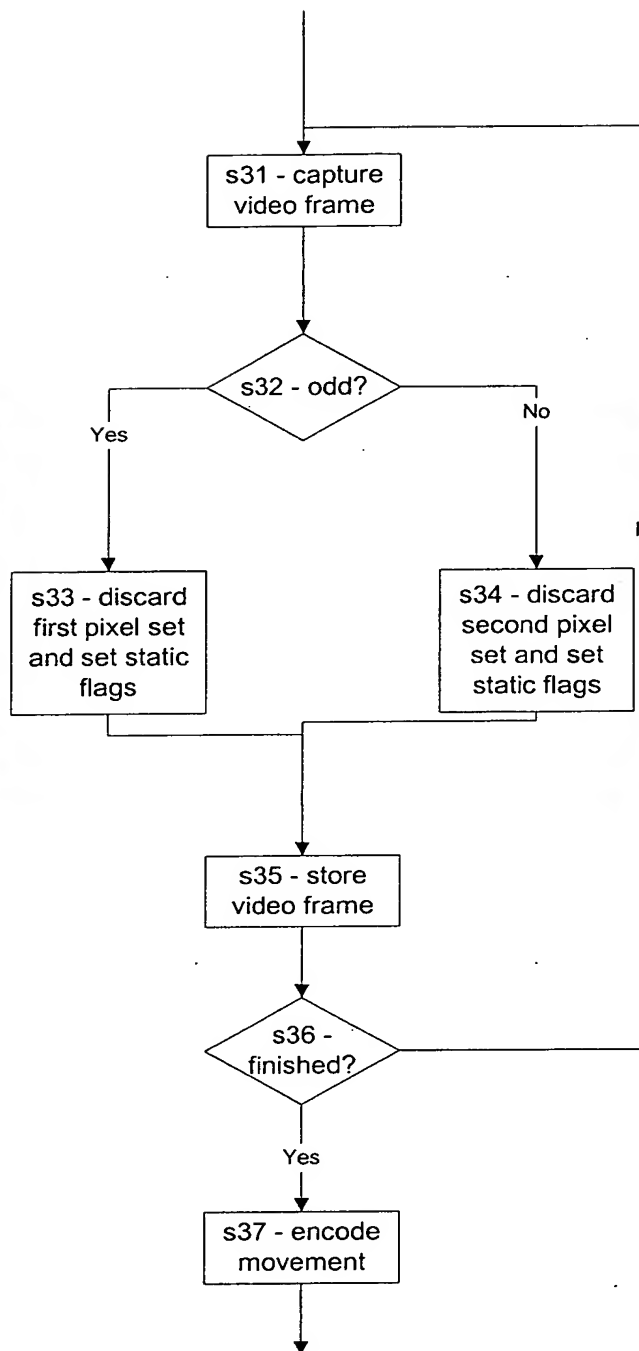
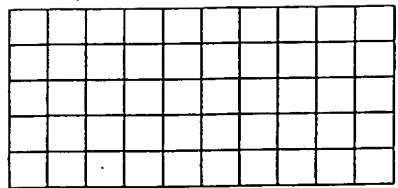
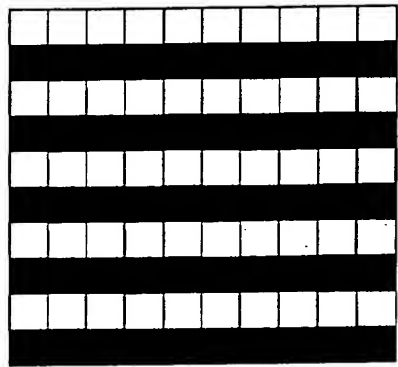
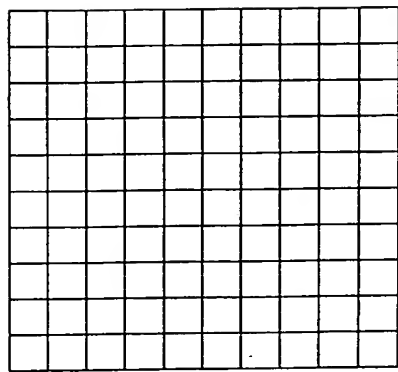


Figure 6

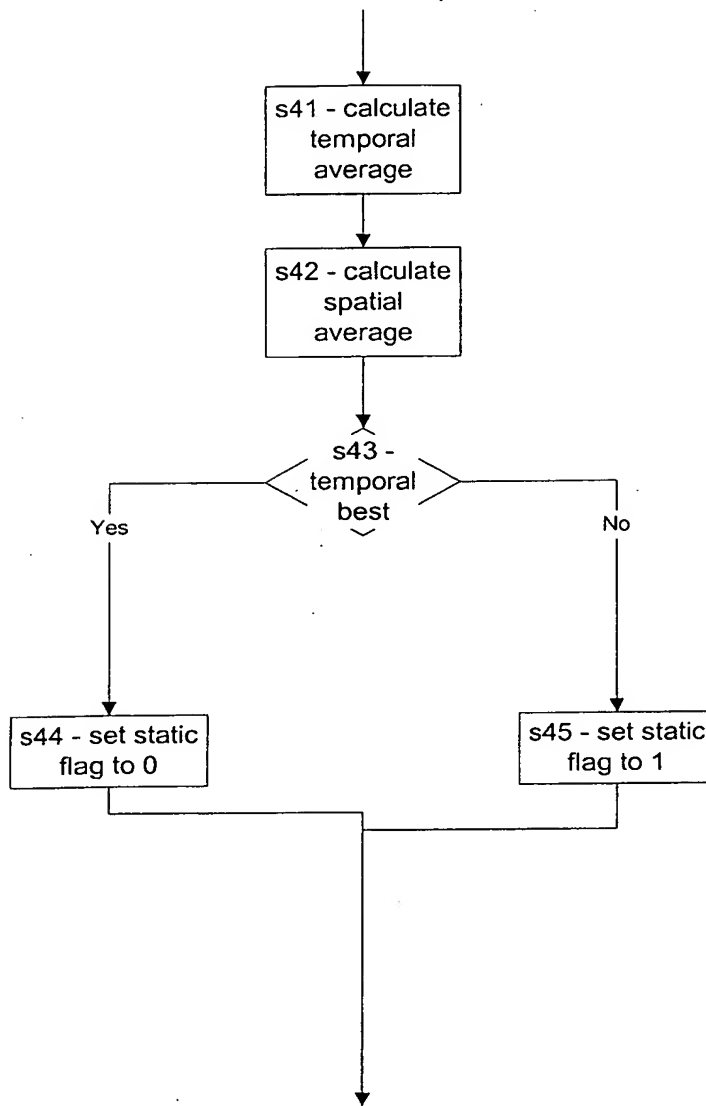


Figure 7

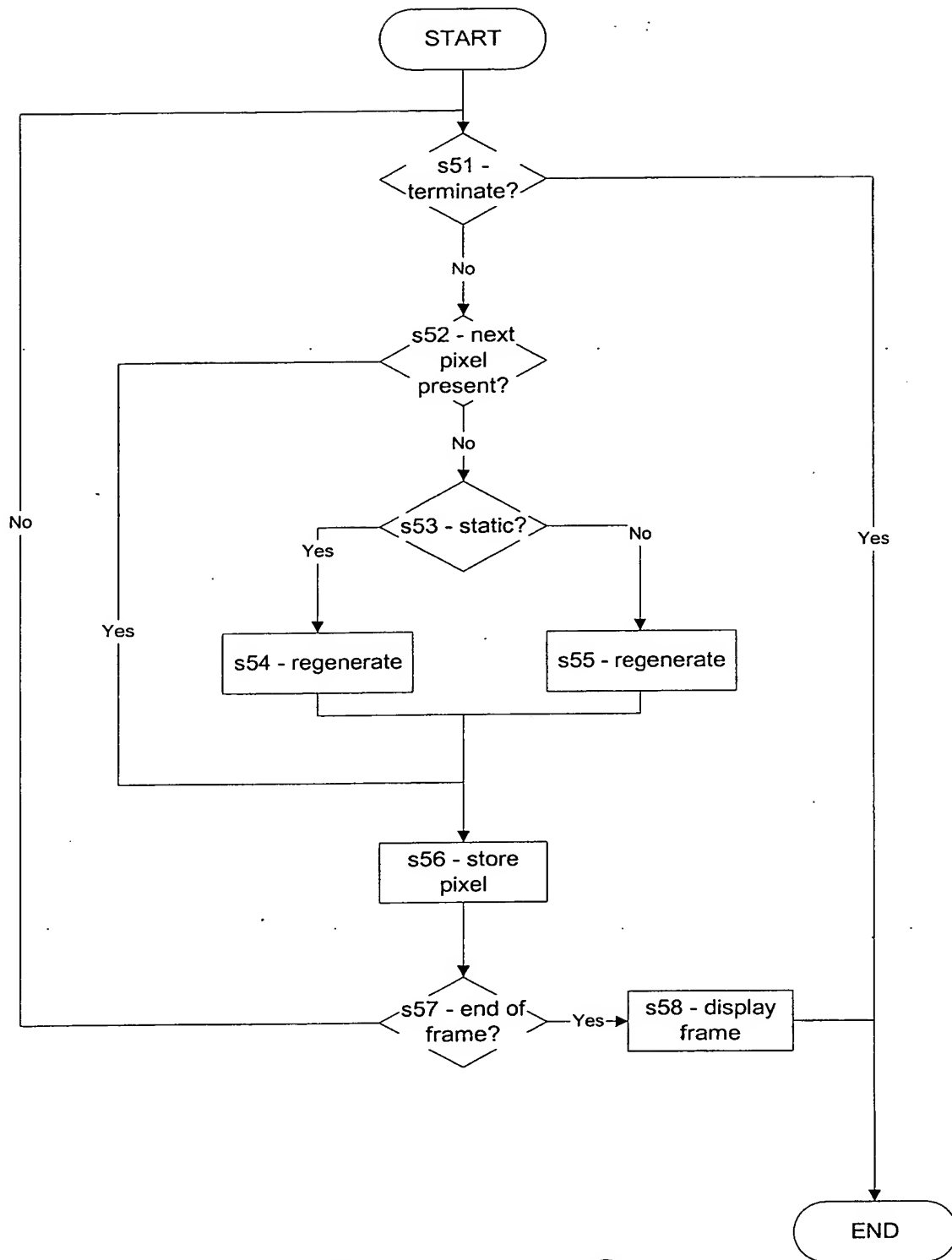


Figure 8

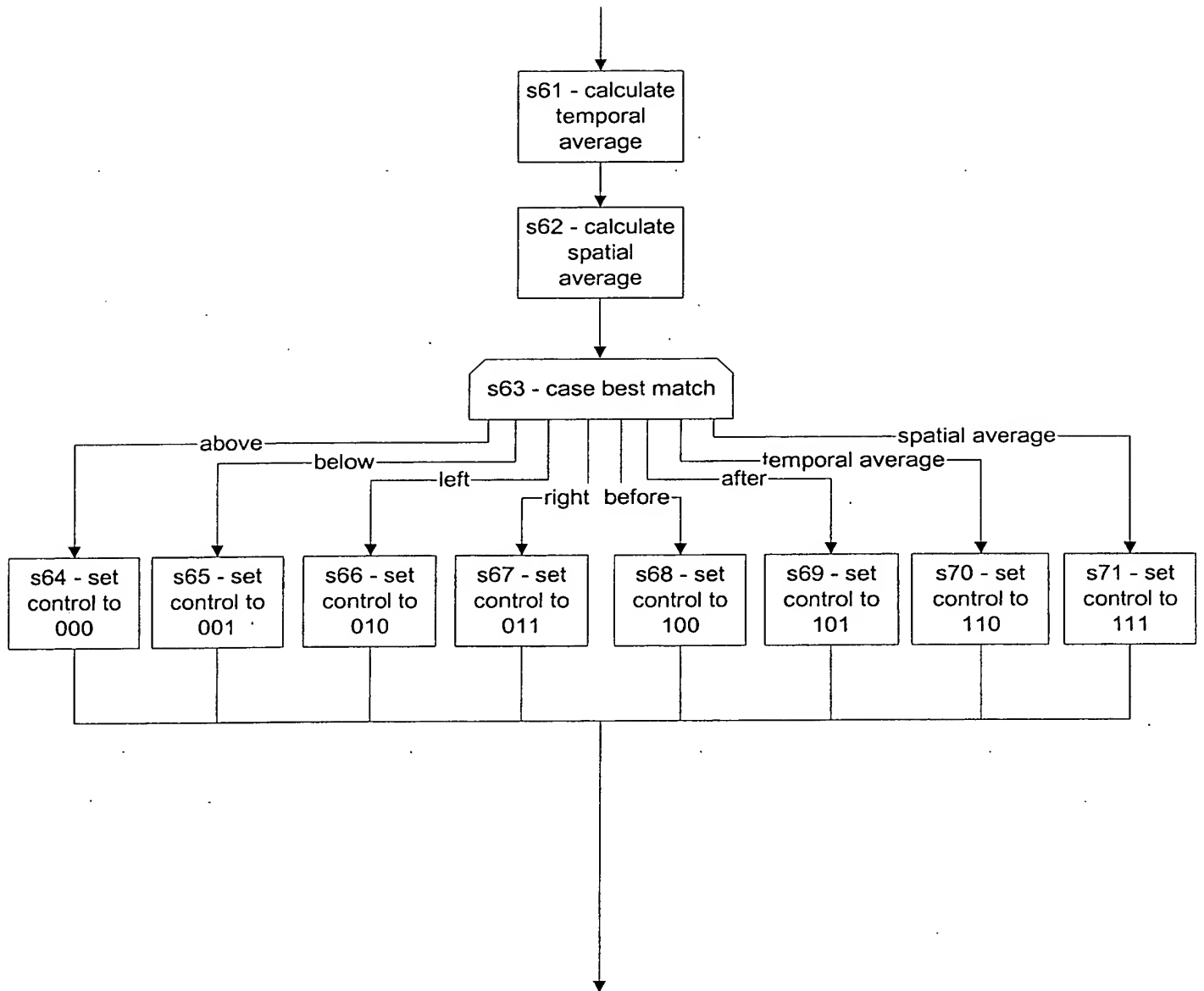


Figure 9

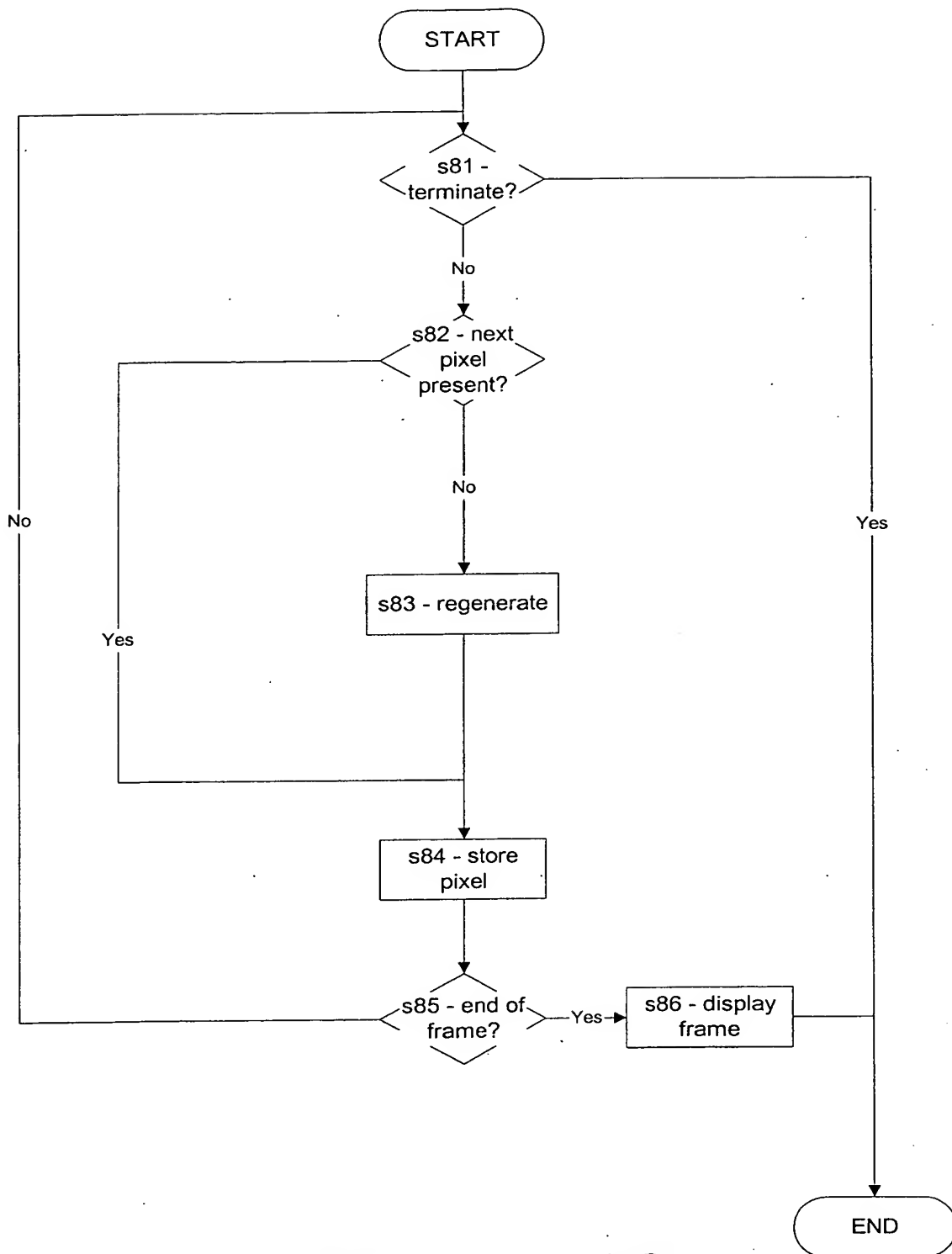


Figure 10

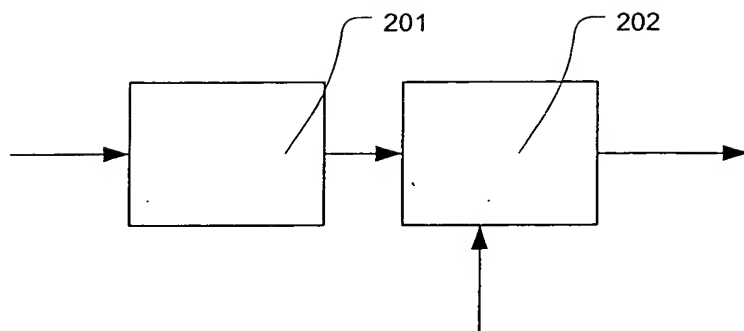


Figure 11

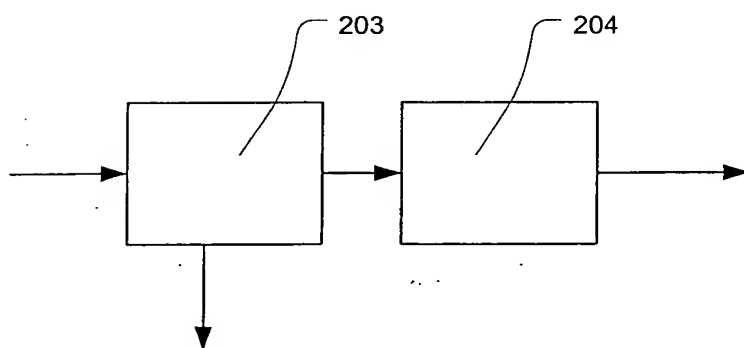


Figure 12